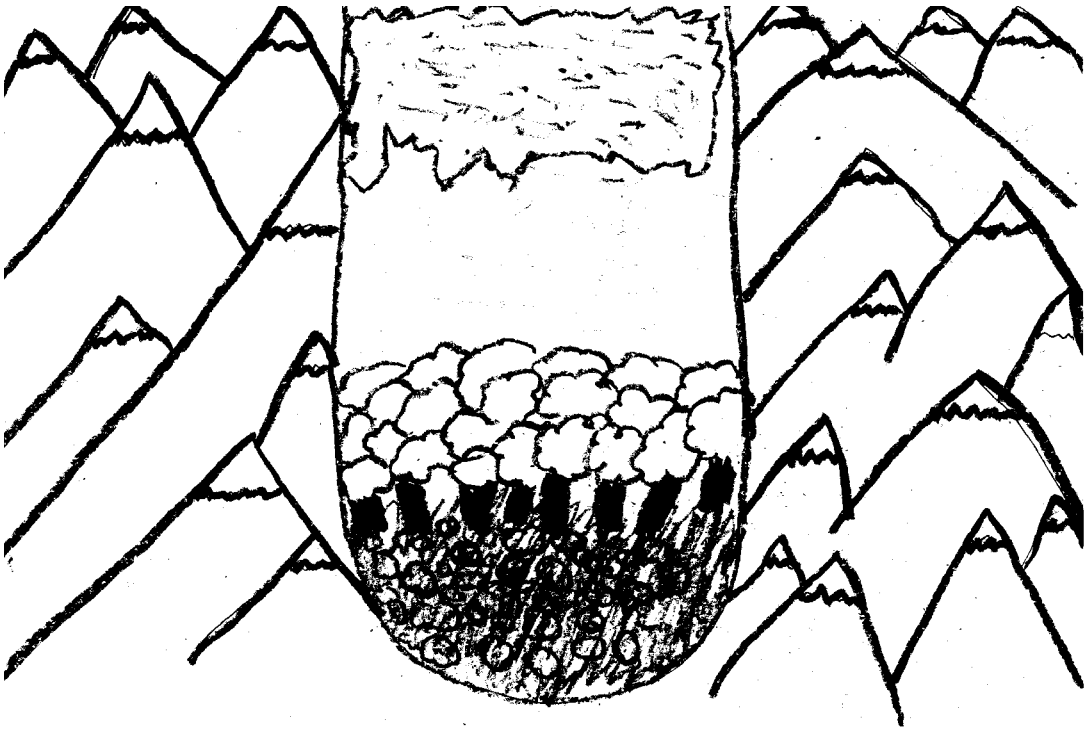
National Park Service
U.S. Department of the Interior

Glacier National Park

Unit 3:
Climate Changes
Glaciers and Glaciation



Glaciers and Erosion
Student Artwork by Jeri Boggs

Climate Changes Teacher Background Information

This unit is really a continuation of "Mountains and Mountain Building" (Unit 2) - helping students understand the concept of glaciation and its effect(s) on mountain ecosystems. Glacier National Park is named for the glacially carved valleys and features throughout the park-not for the current glaciers in the park (as many people believe). U-shaped valleys, moraines, and grooves abraded into bedrock are direct evidence that glaciers have come and gone. They are likewise evidence that Earth's climate has been dramatically different in the past.

The Student Reading for Unit 3 contains cultural stories dealing with climate change and glacial erratics. It also contains a story about glaciers - how they grow, move, and change the landscape. It contains a lot of glacial terminology, which is interesting, highly descriptive, and may seem a bit exotic to students not familiar with northern landscapes. Many of the terms have few applications outside the description of glacially carved terrain. The lessons in this unit will help students explore and internalize the vocabulary and concepts to enhance their understanding and appreciation of the topography of Glacier National Park and its uniqueness in the world.

Glaciation: The Ice Age – 2 million years ago

The geologic event that would define the landscape began with a global cooling trend approximately 2 million years ago. The Pleistocene Ice Age saw large ice sheets repeatedly advance and retreat throughout the temperate regions of North America until about 10,000 years ago. In the area that would become Glacier National Park, ice advanced and retreated until probably melting completely about 12,000 years ago. During the ice advances, the lower valleys were filled with glaciers and only the very tops of the higher peaks were visible. The "rivers of ice" sculpted the mountains and valleys into a variety of landforms associated with major alpine and valley glacial action. Even though the Ice Age glaciers are gone, the results of their passing are evident on the landscape. Massive U-shaped valleys, numerous cirque lakes or tarns, horns, cols, moraines, and aretes are but a few of the glacially carved landforms that contribute to the beauty of Glacier.

To view a map of where the remaining glaciers are in the park or see repeat photos visit the U.S. Geological Survey website.

Recent Glaciation – dating from about 6,000 years ago

Today, we are living in a relatively warm interglacial period. All remnants of the Pleistocene ice have disappeared. There are no active glaciers in Waterton Lakes National Park; however, the last survey in Glacier National Park resulted in 25 named alpine glaciers. They are of relatively recent origin, having formed in the last 6,000 to 8,000 years. They probably grew rapidly during the Little Ice Age that started about 400-500 years ago and ended about 1850. However, they work in the same way as larger glaciers of the past.

A glacier forms when more snow falls each winter than melts the next summer. With alternating freezing and thawing, the snow becomes granular ice. As these layers build up, the ice recrystallizes, becomes denser, and eventually forms a massive sheet. The ice needs to be about 100 feet thick for a glacier to form and have a surface area of at least 25 acres.

Ice near the surface of the glacier is often hard and brittle. Due to the pressure of ice above, the ice near the bottom of the glacier becomes flexible. This flexible layer allows the ice to move. Depending on the amount of ice, the angle of the mountainside, and the pull of gravity, the ice may start to move downhill. Once the ice begins to move, it is called a glacier.

As the ice moves, it plucks rock from the sides and bottom of the valleys. Rocks falling on the glacier from above mix with the glacial ice as well. Over long periods of time the sandpaper-like quality of the moving ice and rock scours and reshapes the land into broad U-shaped valleys, sharp peaks, and lake-filled basins.

Tree-ring studies indicate that retreat of the recent glaciation began about 1850. When Glacier National Park was established in 1910, there were more than 150 glaciers within the national park compared to about one fourth of that number now. Retreat rates appear to have been slow until about 1910. There was a period of rapid retreat during the mid- to late 1920s. This corresponds to a period of warmer summer temperatures and decreased precipitation in this region. Several of the larger glaciers separated into two smaller glaciers at this time. The Jackson and Blackfoot Glaciers separated as did the Grinnell and Salamander Glaciers. If the current rate of recession continues, it is estimated that there won't be any glaciers in Glacier National Park by 2030. How old will your students be then?

National Park Service Archeology Program-Ice Patch Archeology and Paleoecology in Glacier National Park

Ice Patch Archeology Study, www.glacieriepatch.org
Unlike glaciers, ice patches do not move at all, so encased objects remain in the same spot. Researchers studying ice patches identify and document artifacts and organic materials left behind as the ice melts. Such finds can include animal bones and scat, leaves deposited by wind, fragments of ancient wood, and lost Native American artifacts. From 2009-2013, a collaborative research team investigated 46 of Glacier National Park's ice patches. The Glacier National Park Ice Patch Project's purpose was to document ice patch melting, collect remains of ancient plants and animals, and to protect Native American cultural artifacts associated with hunting and travel in Glacier's high-elevation regions.

Glacier National Park has always been iconic for its beautiful mountain landscapes, and is now unfortunately the 'poster child' for climate change-related losses of glaciers, ice patches, and the values associated with alpine and sub-alpine landscapes, ecosystems, and heritage values. The Glacier Ice Patch Archeology and Paleoecology project has yielded scientific and cultural information about past climates and cultures that can inform resource stewards as well as capture the public imagination.

Archeologists survey ice patch edge for cultural artifacts, NPS photo.

A Trip to Glacier to look at Geology

Two of the most accessible valleys in the park - Lake McDonald and St. Mary- are both excellent sites to observe many glacially carved features and contain the two largest glacially formed lakes in the park. Apgar is located at the base of Lake McDonald and the village of St. Mary is at the base of St. Mary Lake. The glacial troughs in which they lie afford an uninterrupted view of the work of ice.

At Home In This Place
DVD Content
Play Videos:
Kootenai - *The Place Where They Danced*

Apgar

For a trip to Apgar, students will experience first-hand the role glaciers have played in shaping the scenery of the Lake McDonald Valley. They will be able to see; lateral and terminal moraines, U-shaped valleys, glacial striations, glacial outwash, till, and erratics.

At Home In This Place
DVD Content
Play Videos:
Kootenai - *We Ask That You Walk Lightly*

Additionally, a trip to the Apgar area will bring students to the setting for the Kootenai story, *The Place Where They Danced*. A video of Vernon Finley telling this story is on the *At Home in This Place* DVD. Also included on the DVD, W*e Ask That You Walk Lightly*, re-affirms the significance of this place to the Kootenai and reminds all visitors to be good stewards and respectful here.

The View Up-Valley from Apgar

Because Lake McDonald lies to the west of the main block of mountains that make up Glacier National Park, and because it was carved out of younger, softer sediments than those in the St. Mary Valley, the McDonald Valley trough is almost straight. When you look up the lake you can see the back of Mount Gould which also overlooks the Many Glacier Valley on the east side of the park. Mount Gould is a horn in the middle of an extensive arete called The Garden Wall. The Garden Wall was part of the headwall for the McDonald Valley Glacier. The back side of the Garden Wall formed the headwall for the Many Glacier Valley. Directly behind The Garden Wall, just to the left of Mount Gould, lies Grinnell Glacier, a young glacier unrelated to the massive Ice Age glaciers.

While occupying the long valley in front of you, the McDonald Valley Glacier also filled an equally large area to the left of the Garden Wall-the extensive McDonald and Mineral Creek drainages. Near the far end of the valley and to the right, there are two dramatic hanging valleys carved by the Hidden Lake and Avalanche Lake glacial tributaries. The two long ridges to the left and right of the lake are lateral moraines. Howe Ridge is on the left and Snyder Ridge is on the right. You are standing near the end of the valley. The lake is nearly 500 feet deep and has been partially filled with a great deal of glacial outwash material. Imagine how thick the McDonald Valley Glacier must have been in order to deposit that much material along its flanks!

The Apgar Mountains, behind and to your left, and the Belton Hills, to your right, forced the snout of the glacier to squeeze through the narrow valley. Glacial outwash extends far into the Flathead Valley from this point, but all of the moraine materials along both sides of the lake are glacial till. Lower McDonald Creek flows over the valley floor formed of

Looking Up Lake McDonald Valley, NPS photo (Glacier Student Guide CD).

glacial outwash. Apgar Village is located on the terminal moraine of the McDonald Valley Glacier.

St. Mary

St. Mary Lake is not impounded by a moraine like Lake McDonald. Upper and Lower St. Mary Lakes, known as the "Lakes Inside" or the "Walled in Lakes" by the Blackfeet, were formed when glacial outwash sediments originating further up the valley were deposited on top of a partially melted valley glacier. Deposition on the lateral margins was heavier than over the top of the remnant ice mass. When the ice in the center of the trough finally melted completely, the "Lakes Inside" were left as kettle lakes on an extensive outwash plain. The lakes were probably one continuous lake to begin with, but continuing outwash materials from Wild and Divide Creeks filled in the waist of the continuous lake to make two lakes, with a short river between the two. The river between them continues to cut down through the outwash materials.

The view Up-Valley from St. Mary

It was only about 20,000 years ago that the glaciers began their retreat up the valleys. They have come and gone at least four times in the last 2 million years. From St. Mary you can look up the length of the glaciated valley toward Logan Pass, where many smaller tributary glaciers joined with the main valley glacier. Other tributaries left hanging valleys along the length of the lake. To the southwest, you can see where Red Eagle Mountain tapers into a medial moraine which separated a branch of the main glacier that had worked its way down Red Eagle Valley. At one time, this medial moraine may have extended further along the south side of Upper St. Mary Lake, but river erosion has cut some of it away in the last 20,000 years. The thick forests, which lie below Curly Bear Mountain and along the southeastern shore of the lake, grow in a fertile lateral moraine left on that side of the glacial trough. A lateral moraine was deposited along the base of Singleshot Mountain, extending along the west side of Lower St. Mary Lake and the west side of Highway 89 into Canada. The terminal point for one of the advances of these glaciers may have been as far to the northeast as Lethbridge, Alberta. The moraine tapers considerably as you move north and has been cut through by a number of tributary glacial river valleys along the way.

When you look to the east you can see the impressive St. Mary Ridge, a lateral moraine that extends along the eastern side of the St. Mary Valley into Canada. On several occasions during the last two million years, the valley glaciers on this side of the park interfaced with continental ice sheets that advanced from the northeast. Further to the north of St. Mary, there are many sites where continental glacier till is inter-layered with valley glacier till. In the road cut across Divide Creek from the park employee housing area, geologists have found lake bottom silts that are inter-layered with valley glacier till. At this location a large glacial lake, formed by melt water from a retreating continental ice sheet, had its western shoreline along the edge of the mountains.

Looking Up St. Mary Lake, B.R. McClelland photo (Glacier NP Digital Image Library).

Unit 3 -Climate Changes: Glaciers and Glaciation
Lesson 1
Breaking it Down

Materials:
- Student Reading Unit 3
- Access to a freezer
- A tray
- A glass bottle or jar with a tight lid (thin glass on the jar, may help dramatize the demonstration)

Crevasses-Jackson Glacier, J. Mohlhenrich photo (Glacier NP Digital Images Library).

Lesson At A Glance

Students observe a concrete example of water weathering rocks by freezing a jar of water and then letting the broken jar with ice, un-thaw to illustrate power of ice in weathering rocks.

Objectives

Students will:
- Infer what will happen if a jar filled with water is put in the freezer overnight.
- Observe that as water freezes, it changes form, expands and produces force.
- Relate how water expanding when it freezes, weathers rocks.
- Identify moving ice as the primary component of a glacier.

Time Required

50 minutes. Additional time if field trip added to this unit.

Vocabulary

Bergschrund, expand, freeze, glacier, ice patch, thaw (additional vocabulary in Student Reading.)

Teacher Preparation/ Background

This activity is designed to have students think about the power of water as it changes from liquid to a solid state when it freezes and expands. Teacher must get access to freezer, students bring jars from home or teacher provides. Make sure you have safety guidelines in place for dealing with broken glass!

Procedures

1. Have students complete the Student Reading, Unit 3 - individually, in groups, or together as a class and complete the "Checking for Understanding Questions." Discuss vocabulary and any new concepts. You may want to show the podcast about the unique geology of Glacier National Park and discuss how the glacially carved valleys of Glacier National Park are what give the park its name. Also, how the vastness of these valleys is one of the park's most awe-inspiring features to many visitors. Review some of the words from the Blackfeet, Kootenai, Pend d'Oreille and Salish about their connection to these mountains and valleys.
2. Tell students you are going to do a short experiment to try to find out how water could break rock. This can be done as a demonstration, or each team could bring in an unneeded, thin glass jar from home. Have teams make sure to label their jars. Fill each jar with water to the point where there is no room for air in the jar, then close the jar tightly.
3. Place the filled jar(s) on a tray and have someone place it in a deep freeze.
4. The next time the class meets to work with glaciers, have someone bring the tray with the jar(s) carefully back to the classroom. Note what happened to the jars. The jar lid should be bulged out and the glass should be cracked. If not all the jars cracked, try to figure out why -lid not tight enough, not enough water, glass too strong and thick.

Reflection and Assessment

Have students make careful observations -but NOT touch their jars. Let the tray sit in a safe place and have them make more observations throughout the day of what happens as the ice melts. How did the shape of the jar change once all the ice was melted? (The glass collapsed in a heap.) Have they ever seen a similar phenomena happen in nature with snow/ice? (This is what actually happens when glacial melt water seeps into headwall rocks and freezes. When the bergschrund gap moves slightly away from the headwall and melting occurs, the surface rocks of the headwall collapse onto the glacier.) The description of the work of glaciers in the student reading mentioned how melt water in a glacier seeps into cracks in rocks and then expands and breaks up the rocks. Erosion of rock by ice expansion is most dramatic near a glacier headwall, but the process takes place anywhere that ice accumulates in the winter and thaws in the summer.

Writing Extension

Use Views of the National Parks (Views) - a program of the National Park Service designed to present the natural, cultural, and historical resources of our national parks and select the topic of glaciers. There are narratives and images on glaciers and glacially carved features from numerous national parks, including a slide show about Glacier National Park.

Have groups of students work together in presenting the information from the different national parks to the class. Compare and contrast the parks

Bergschrund on Sperry Glacier, NPS photo (Glacier NP Digital Image Library).

that have glaciers currently, with those that don't. Make a list of what features can be found in both. Students can email, research on line at www.nps.gov for each park, or write to the different parks to get more information for this discussion.

Action Project/ Field Trip Extension

- Ranger-Led Field Trips and Service Learning Projects in Glacier National Park. Earth Science and Forest Processes field trips about park geology.
- Self-Guided Field Trips in Glacier National Park.
- Glacier Institute - geology and other education programs.
- Flathead CORE - outdoor education guide for field trips in the Flathead.
- Guided Tours in Glacier National Park- various concession operated.

Additional Resources

- Climate Change Resource Guide- includes Facing the Future Lessons.
- Glacier NP Cultural Resource Guide - Fact Sheets, Digital Images, Lessons.
- USGS Repeat Photography Project and Repeat Photo Education Trunk.
- Ice Patch Archaeology Resource Brief, Crown of the Continent Research Learning Center.
- Glacier National Park Ice Patch Project Interactive Website with Kids Page - Confederated Salish and Kootenai Tribes of the Flathead Reservation, the Blackfeet Nation, the Univ. of Wyoming, Univ. of Colorado Boulder, Univ. of Arizona, Glacier National Park's cultural resources program and the Rocky Mountains Cooperative Ecosystem Studies Unit (CESU).
- Flathead Community of Resource Educators Website - contains a resource link to the Flathead Watershed Sourcebook - cultural and natural history.
- Glacier National Park Conservancy Bookstores - books specific to Glacier.

MT Content Standards

Unit 3: Lesson 1, page 43

Montana Common Core Standards—English Language Arts

CCRA.SL.1. Prepare for and participate effectively in a range of conversations and collaborations with diverse partners, building on others' ideas and expressing their own clearly and persuasively.

Standards for Literacy in History/Social Studies, Science, and Technical Subjects

CCRA.RH/ST.1. Read closely to determine what the text says explicitly and to make logical inferences from it; cite specific textual evidence when writing or speaking to support conclusions drawn from the text.

CCRA.RH/ST.4. Interpret words and phrases as they are used in a text, including determining technical, connotative, and figurative meanings, and analyze how specific word choices shape meaning or tone.

CCRA.RH/ST.9. Analyze how two or more texts address similar themes or topics in order to build knowledge or to compare the approaches the authors take.

CCRA.RH/ST.10. Read and comprehend complex literary and informational texts independently and proficiently.

Montana Standards for Science

Science 2.2.4. Model and explain that matter exists as solids, liquids, and gases and can change from one form to another.

Science 1.1.6. Identify, compare, explain ... how observations of nature form an essential base of knowledge among the Montana American Indians.

Montana Standards for Social Studies

Social Studies Standard 1. Students access, synthesize, and evaluate information to communicate and apply social studies knowledge to real world situations.

Social Studies Standard 3. Students apply geographic knowledge and skills (e.g., location, place, human/environment interactions, movement, and regions).

Social Studies Standard 6. Students demonstrate an understanding of the impact of human interaction and cultural diversity on societies.

Indian Education for All Seven Essential Understandings Regarding Montana Indians

*Essential Understanding 1 —tribal diversity

*Essential Understanding 3 —importance of oral traditions

*Essential Understanding 6 —history is subjective

Unit 3- Climate Changes: Glaciers and Glaciation
Lesson 2

Carving Mountains - INSTRUCTIONAL CARVING MOUNTAINS VIDEO

Materials:

- Research materials to include Earth Science texts, books dealing with the geology of Glacier National Park and Montana
- Images of geological features of Glacier National Park, acquired online (request park's Student Guide CD)
- One or more raised relief maps of Glacier National Park
- Paper for recording research
- Several recycled 4' by 4' plywood boards
- Moist, recycled pottery clay or large supply of modeling clay
- Tools for working clay
- An appropriate ruler to establish a reference scale for elevations
- Paper or light cardboard for labels
- Pins to hold labels
- Scissors
- Fine-point pens
- Plastic covering to prevent drying out of models in general
- Good dictionary

Alpine Meadow at Logan Pass, NPS photo (Glacier Student Guide CD).

Lesson At A Glance

Through individual and group research, students create a clay model of a mountain range with glacial features labelled.

Objectives

Students will be able to:

- Compile team dictionaries of mountain and glacial terms.
- Work cooperatively to design and build a mountain range out of clay that contains glacial features.
- Optional: build models to scale.
- Identify landforms in their clay models that have cultural significance.

Time Required

Two class periods - one to do research on glacial terms. The second to construct clay models. Additional time if students want to paint or use models for other presentations.

Vocabulary

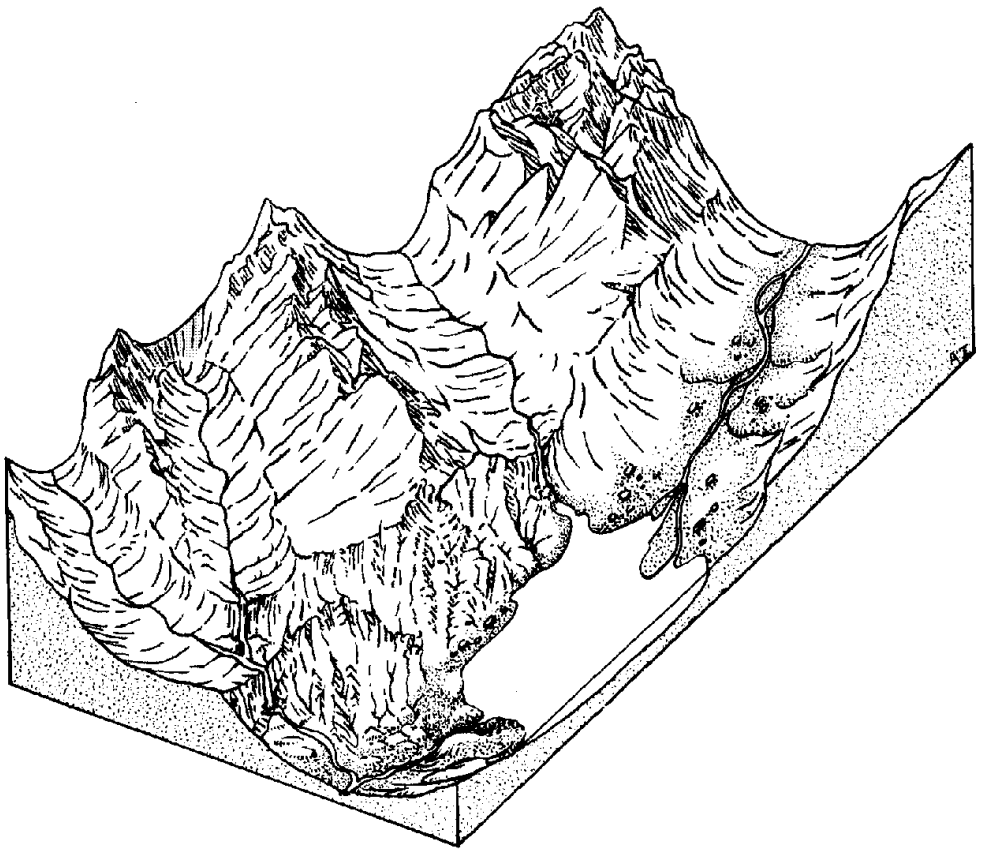
Alpine meadow, avalanche, col, crevasse, esker, fold, glacial trough, glaciation, hanging valley, kettle lake, lateral moraine, medial moraine, moraine, mountain pass, mountain range, outwash plain, peak, plateau, terminal moraine, tree line, valley glacier.

Teacher Preparation/ Background

Make glacial feature labels and or definition cards for each group. Have boards/trays for models to be built on, clay ready and place to put models out. This activity is designed to get students research experience on glaciers and the tactile experience of building a scale model of mountains with glacially carved features.

Procedures

1. Use the vocabulary list provided (and add others of your choosing) as a guide for students to use in compiling team dictionaries of mountain and glacial terms.
2. Divide the students into cooperative learning groups; give each group fresh balls of clay and tell them to sculpt mountain formations on a team board until they are satisfied with what they have done. It will add relevance if students are encouraged to replicate an area of the park with which they are familiar. The raised relief maps of the park are a great resource for this. A math component can be added if students must do it to scale! (1 inch = 1000 feet elevation for example, so a 10,000 foot peak would be 10 inches high).
3. Provide glacial feature labels (or definition cards) to an appointed or chosen chairperson for each team. Ask individuals to identify or remold specific features into the group of mountains. This requires alterations of the original mountains. When there is some question about a formation to be labeled, students may use available books and other resources for immediate research.



Glacial Features- can you find a hanging valley? Glacial trough? (Glacier NP Digital Image Library).

Reflection and Assessment

When the labeling and remolding are complete, the students should be able to define and discuss their work.

Writing and Other Extensions

Using the vocabulary and other terms they came across in their research, each team should generate a dictionary definition of mountain and glacial terms. When dictionaries are completed, students should examine other teams' models and help each other refine formations and definitions. This process will help them to internalize their research.

The next obvious question might be, "What do we do with the clay models when the students finish?" Ask the students! Maybe they would like to paint them, show them to another class or parents, write an adventure story that takes place in the mountains, generate some appropriate weather in their models, pour water over them to trace natural drainage, or make models of indigenous animals and plants to put in their created environments.

Action Project/ Field Trip Extension

- Ranger-Led Field Trips and Service Learning Projects in Glacier National Park. Earth Science and Forest Processes field trips about park geology.
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- Glacier National Park Conservancy Bookstores - books specific to Glacier.
- Tall Tales, (Mechanical Weathering, Glacier Features, Mountain Names, OPI-Indian Education for All Lesson, 5th grade.

MT Content Standards

Unit 3: Lesson 2

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Standards for Literacy in History/Social Studies, Science, and Technical Subjects

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CCRA.RH/ST.9. Analyze how two or more texts address similar themes or topics in order to build knowledge or to compare the approaches the authors take.

CCRA.WHST.7. Conduct short as well as more sustained research projects based on focused questions, demonstrating understanding of the subject under investigation.

Montana Standards for Science

Science 1.1.4. Use (create, analyze) models that illustrate simple concepts and compare those models to the actual phenomenon.

Indian Education for All Seven Essential Understandings Regarding Montana Indians

Essential Understanding 1 —tribal diversity

Essential Understanding 3 —importance of oral traditions

Essential Understanding 6 —history is subjective

Unit 3 -Climate Changes: Glaciers and Glaciation
Lesson 3
Model Glaciers - INSTRUCTIONAL MODEL GLACIERS VIDEO

Materials:
- Small sandbox or trough from Unit 2
- Sand, gravel and assorted small rocks
- Variety of sizes of elongated plastic containers for freezing water in.

Mokowanis River drainage- a popular hiking trail today - was used throughout history for travel across the Continental Divide. Can you pick out any glacially carved features? NPS photo.

Lesson At A Glance

Using river trough from Unit 2, students place/move frozen ice blocks with gravel/rocks in them through the sand to form glacially carved valleys, cirques, tarn lakes, etc.

Objectives

Students will be able to:
- Form glacial features in a sand box model river valley.
- Identify glacial features on the landscape - terminal and lateral moraines, the headwall, cirques, tributary glaciers, and hanging valleys.

Time Required

Overnight to freeze "glacier" containers. One class period to form glacial features in sand. Additional time to have ice blocks melt to see tarn lakes and till.

Vocabulary

Till, tributary, U-shaped valley, V-shaped valley, valley glacier.

Teacher Preparation/ Background

Freeze gravel and small rocks into ice blocks so they will have a rough base when they start to melt. Then thaw them enough day of class to get them out of the containers. Keep the sand, gravel, and rocks in the sandbox damp enough to mold into mountains.

Procedures

1. Have the students form mountains and river valleys in the river sand trough.
2. Take out the prepared ice blocks that have stones frozen into them. Use a large ice block to represent a large mountain glacier and several smaller blocks to represent smaller tributary glaciers.
3. Place the large block at the head of the valley the students have created in the sand and slowly bulldoze a path down the river valley. Point out the gouging and plucking along the way. When you reach the terminal point of the valley, point out the terminal moraine. Be sure that you are gouging nearly to the bottom of the sandbox or trough. Point out the lateral moraines along the side of the glacier's path.
4. Give some of the students small glaciers and invite them to work a few tributary glaciers. Ask if they can produce hanging valleys, cirques, etc. . When they have finished have them leave their remnant glaciers against the headwalls.

Reflection and Assessment

Some time later have the students look at the debris left in the cirque as the ice block melts. Ultimately there will only remain a little pile of "till" and a small "tarn" lake if the clay layer in your trough keeps the water from all draining out.

Culinary Extension

As a special treat and review, get several half gallon blocks of Neapolitan ice cream, marshmallow cream topping, ground nuts to represent rocks, and whatever else you might find tasty and relevant. Then get down to business with an ice cream scoop. While reviewing glacial terminology and carving formations with the scoop, fill cups for the students who can correctly identify the latest formation.

Action Project/ Field Trip Extension

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MT Content Standards

Unit 3: Lesson 3, page 49
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